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Does the CDM discourage emission reduction targets in advanced developing countries? [1]

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Abstract

Under the Kyoto Protocol, developing countries can voluntarily participate in climate change mitigation through the Clean Development Mechanism (CDM), in which industrialized countries, in order to meet their mitigation commitments, can buy emission reduction credits from projects in developing countries. Before its implementation, developing-country experts opposed the CDM, arguing that it would sell-off their countries' cheapest emission reduction options and force them to invest in more expensive measures to meet their future reduction targets. This 'low-hanging fruit' argument is analysed empirically by comparing theoretical marginal abatement cost curves. Emissions abatement costs and potentials for CDM projects are estimated for different technologies in eight countries, using capital budgeting tools and information from project documentation. It is found that the CDM is not yet capturing a large portion of the identified abatement potential in most countries. While the costs of most emissions reduction opportunities grasped taken are below the average credit price, there are still plenty of available low-cost opportunities. Mexico and Argentina appear to use the CDM mostly for harvesting the low-hanging fruit, whereas in the other countries more expensive projects are accessing the CDM. This evidence at first sight challenges the low-hanging fruit claim, but needs to be understood in the light of the barriers for the adoption of low-cost abatement options.

Keywords: Climate change mitigation, Kyoto Protocol, Clean Development Mechanism (CDM), Abatement costs, Low-hanging fruit problem, Marginal abatement cost curve

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1. Introduction

Under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, developing countries can voluntarily participate in climate change mitigation through the Clean Development Mechanism (CDM). Emission reduction credits - Certified Emission Reductions (CERs) - from projects in developing countries can be bought by industrialized ones[1], who use them to meet their own reduction commitments. While its main goal is ensuring cost-effectiveness of mitigation measures, the second aim of the CDM is to benefit host developing countries through technology transfer and investments in sustainable development, thus contributing to their transition to a more climate-friendly economy.

Before full-scale implementation, developing-country experts opposed the CDM, arguing that using it would imply selling off developing countries' cheap emission reduction options (the so-called 'low-hanging fruit') to industrialized countries, with the result that developing countries would have to invest in more expensive measures to meet their own future reduction targets.[2] While the CDM is a cost-containment mechanism and as such is supposed to target the cheap emission reduction options, the low-hanging fruit focus of the CDM has also been criticized from a developed-country perspective, on the grounds that the subsidy granted by the mechanism to very large, low-cost projects is disproportionately large compared to the cost of implementing the emission reductions (Wara, 2006). Despite these concerns and criticisms, the CDM has grown successfully, even in the countries initially most sceptical of it e.g. China (see Tangen and Heggelund, 2003; Bang et al., 2005). As of December 2009, over 5000 projects have been proposed and 1.1 billion tonnes CO_2e of emission reductions are expected to be achieved by 2012 (URC, 2010). For the last three years, monthly project inflows averaged more than 100 and have not been touched by the financial crisis to date.

These arguments are likely to play an important role in the international negotiations towards a new climate regime post-2012. There is considerable pressure on fast-growing developing countries to take up some kind of emission reduction commitments. Firstly, it is now recognized that future global emissions reduction targets need to be much more ambitious than the Kyoto target for avoiding dangerous climate change. Secondly, some large and fast-growing developing countries already emit such high levels of greenhouse gases (GHGs) that their participation is regarded as crucial for avoiding dangerous climate change (Bang et al., 2005; Gupta et al., 2007; Höhne et al., 2007; Parry et al., 2007; WRI, 2008).[3] Thirdly, concerns about the impacts of climate policy - on a country's competitiveness in the global markets and the likelihood that energy-intensive industries migrate to countries without emission reduction targets - have been prominent in research and policy debates (see e.g. Hourcade et al., 2001; Baumert and Kete, 2002; Cosbey, 2005; Barker et al., 2007; High Level Group on Competitiveness, Energy and the Environment, 2007). All these concerns have led to increasing demands by industrialized countries that advanced developing countries take up emission reduction commitments.

Developing countries, however, oppose committing to reduction targets. Their main arguments are the historical responsibility of industrialized countries for existing carbon concentrations in the atmosphere; the negative impact that reduction targets might have on their development, poverty alleviation and growth expectations; and notions of fairness in the amount of emissions a person is allowed to generate in developing countries as compared to industrialized ones. For detailed accounts of different countries' positions in the international negotiations towards new climate commitments, see Bang et al. (2005) and, more recently, Höhne et al. (2007) and WRI (2009).

The CDM experience is playing a role in the climate negotiations as well. Some developing countries and environmental Non-Governmental Organisations (NGOs) consider the CDM to be a means for industrialized countries to shift their emissions reduction responsibility to other countries. Based on its project-by-project nature, critics argue that it creates disincentives for developing countries' governments to pass climate-friendly legislation.[4] Due to the large financial flows achieved by the CDM, industrialized countries feel uncomfortable that the desire to continue receiving these funds is itself a reason for advanced developing countries not to take more ambitious climate change mitigation actions (EU Commission, 2009; US Government Accountability Office, 2008). Moreover, the costs of mitigation actions, coupled with the above-mentioned fear that the CDM has already captured the cheapest ones, make developing countries even more unwilling to commit.

This argument is empirically tested, thus contributing to the discussion on the role of offset mechanisms in achieving global GHG emission reductions. So far, most of the research on the low-hanging fruit claim has been theoretical and model-based, and thus no empirical evidence for its validity has yet been presented. With the large number of CDM projects in the current portfolio, this is now possible.

The existing literature on the low-hanging fruit claim is first reviewed. The approach for testing this claim using marginal abatement cost curves is then detailed and the emissions abatement cost of CDM projects using the financial information provided in their Project Design Documents (PDDs) is estimated. A dataset of projects, technologies, estimated costs and expected amount of emission reductions is built for eight CDM host countries and summarized in the form of CDM-specific abatement cost curves. These curves are compared with existing abatement cost curves from the literature, in order to determine whether only or mostly the cheapest abatement options are being captured by the CDM. Conclusions for the CDM, the low-hanging fruit argument and its relevance for the ongoing climate negotiations follow.

2. Literature review

The low-hanging fruit issue – also known as the 'sold-out' hypothesis, the 'cherry-picking' or the 'cream-skimming' problem – was already a discussion topic during the negotiations that led to the implementation of the CDM. It is the claim that developing countries will be worse off after selling their cheapest abatement options (the low-hanging fruits) to industrialized countries through the CDM, because they will have to invest in more expensive options later, when they assume own emission reduction targets.

So far, only theoretical analyses of the low-hanging fruit problem have been available in the literature. The results of the studies by Olsen and Painuly (2002), Akita (2003), Bréchet et al. (2004), Germain et al. (2007) and Narain and van't Veld (2008) imply that the existence of a low-hanging-fruit problem basically depends on the evolution of carbon credit prices, the way in which future abatement commitments for developing countries are set, whether CDM projects are developed unilaterally or bilaterally, the market power of the participating countries and the possibility to bank credits from one commitment period to the next.

But several more general characteristics of the climate regime give shape to this interpretation. First, it assumes a necessary condition that developing countries, especially the more advanced ones, will eventually 'graduate' and commit to their own GHG emission reduction targets (Akita, 2003). This is at present one of the most controversial debate topics in the international negotiations towards a post-Kyoto agreement. While Kyoto presupposes such a transition and industrialized countries are trying to push for it, the existing rules do not explicitly include it, and most developing countries are currently against it.

Second, the availability of CDM project options is not only influenced by the cost of the abatement measures, but is also constrained by financial, technical and institutional barriers in the host countries and by the CDM rules themselves. In particular, the high CDM transaction costs and cumbersome registration procedures may prevent attractive abatement options from accessing the mechanism (especially if they are small-scale). While this situation is expected to improve with new CDM modalities, it is likely that some of these cheap abatement options will contribute to the host country's own reduction targets in the future. This also applies to project types that are currently not accepted in the CDM, such as avoided deforestation and many other land use change projects, and the use of nuclear energy. Further, only those projects considered 'additional' can be registered as a CDM. If currently expensive mitigation options become cheaper, they might no longer fulfil the additionality criterion – if one uses low-hanging fruit terminology, the fruit starts to 'rot'.

Furthermore, new emissions abatement options may appear and become cheaper in time as technology evolves and as economies grow. The pool of abatement options is thus not a static one but may grow in the future, especially in developing countries.

Finally, there is an international market for carbon reduction certificates. Assuming a continuation of the current regime, even after a country graduates, there will be other developing countries still under the CDM system, which may continue to deliver cheaper carbon credits (Narain and van't Veld, 2008). Similarly, as abatement options in some countries become scarce or more expensive, other countries now under-represented in the CDM will become more mature and enter the market more actively.

3. The low-hanging fruit issue

To model the low-hanging fruit issue, Rose et al. (1999) draw on the theory of resource exhaustion, whereby there is a resource stock (carbon emission mitigation options) that is exploited and gradually depleted, which results in rising costs of implementation for emission mitigation projects over time. This approach is followed here and it is assumed that part of the stock of emission reduction options in developing countries is captured by the CDM. By comparing the complete stock to the portion captured by the CDM, conclusions are drawn on whether the low-hanging fruit argument holds.

This approach implies a strong simplification of reality, as it does not take into account the carbon market dynamics that, according to the literature, influences the availability of emission reduction options. Both emissions trading and banking – the possibility to save carbon credits earned today for using them in a future period – relax the problem of exhaustion of emission reduction options, as they increase flexibility in achieving reduction targets. Economic growth and technological change will make new emission reduction options appear, so that the abatement stock is replenished. Learning effects and technology diffusion will make these new emission reduction options become cheaper in time, so that there will be new low-hanging fruits to pick.

However, at a given moment in time, it can be assumed that the stock of abatement options available is fixed. As a result, our test of the low-hanging fruit problem relies on two hypotheses:

- Size hypothesis: The larger the portion of the country's mitigation potential (measured in tCO_2e) that has been captured by the CDM, the more likely there is a low-hanging fruit problem.
- Cost hypothesis: The larger the portion of the country's *cheap* emission reduction options that has been captured by the CDM (measured in tCO_2e), the more likely there is a low-hanging fruit problem.

If the CDM is not exhausting the stock of abatement options under the extreme assumption of no dynamics, the actual situation must be even better, because the stock will grow in the future. Thus, this assumption leads us to a strong, robust conclusion.

Our conceptualization of 'cheap emission reduction options' relies on the carbon market: 'cheap' is defined as all those emission reduction options whose abatement costs are below the average carbon market price for CERs. This is in line with the notion that the market will influence the choice of emission reduction actions: if the market price does not compensate for the cost of mitigation, then it is not financially attractive to engage in this action, and it is preferable to trade carbon credits in the market.

4. Marginal abatement cost curves

The discussion on the low-hanging fruit issue builds on the interaction between GHG emissions abatement costs and potentials. Abatement costs describe the costs society has to bear to reduce one tonne of CO_2 emissions – or the equivalent amount of other greenhouse gases – using a certain mitigation activity. They determine the cost-effectiveness of individual policy or project choices. Abatement potentials – the volume of emissions reductions that can be achieved by applying a specific technology in a specific region or country in a certain period of time – describe the amount of mitigation that is feasible. Costs and potentials for different technologies in a country or region are usually displayed graphically together to form a marginal abatement cost curve (MAC).

MAC curves are used extensively in environmental economics to link a firm's (or a country's) pollutant emission levels and the cost of each additional unit of pollution reduction (McKitrick, 1999). Examples of the use of MACs at the firm and at the country level can be found in McKitrick (1999), Ellerman and Decaux (1998) and Criqui et al. (1999). MAC curves for climate mitigation can be derived using a top-down approach by means of macroeconomic models with a detailed energy sector component. They can also be obtained on the basis of engineering data of emission reduction technologies using a bottom-up approach (Criqui et al., 1999).

Climate-economy models use these curves systematically (see e.g. Kuik et al., 2009, for a meta-analysis). However, abatement cost estimates are frequently based on expert opinion, or on model assumptions regarding, among others, the climate policy target, the emissions baseline, discounting rates, and future technological options. Further, there are only a few abatement cost and potential studies that focus on developing countries. Two good examples are the efforts by Wetzelaer et al. (2007) and Bakker et al. (2007) to build an abatement cost curve for these countries in the years 2010 and 2020, respectively. Recently, the consultancy McKinsey has started to develop global and country-specific MAC curves for the year 2030, which have eagerly been taken up in the international climate policy debate (see Enkvist et al. 2007 for an overview). However, as the assumptions and methodology used in the McKinsey curves are not publicly accessible, in this study only bottom-up MAC curves and abatement cost and potential estimations, with more transparent assumptions that are easier to control for and discuss, were used.

Still, a drawback of the reliance on abatement cost curves is that they usually only include the direct investment and operation costs of the abatement options, overlooking potential information and transaction costs that can make them much more difficult to implement in practice.

5. Data and methods

5.1 CDM cost data

CDM project information is available from a public database, the CDM pipeline, which is updated monthly by the UNEP Risoe Centre (URC, 2010). More specific information for each project is also available in the project documentation that can be downloaded from the UNFCCC website.[5] This documentation often includes a financial analysis, as this is one possible method for demonstrating that a project complies with the CDM requirement of additionality: if the analysis shows that the project needs the subsidy from the CDM to be financially attractive, then it is deemed additional. The alternative method for demonstrating additionality is a barrier analysis: if the proponent demonstrates convincingly that there are substantive barriers that prevent the project from taking place without CDM support (such as technological barriers or difficulties in accessing financing), then the project is considered additional.

While this is the only CDM-specific source of financial data that is easily available for compiling a comprehensive dataset, there is a risk of selection bias because information comes only from those projects choosing to use a financial analysis for additionality demonstration. Indeed, one could think that it is precisely the projects using the barrier analysis which are the low-hanging fruits, and that they do not present their financial data because they are so cheap that they would not pass the additionality test if they did. This suspicion is shared by the CDM regulators, as can be seen in the proposal by the CDM Methodology Panel to enhance the barrier test for projects that are likely to have high revenues (CDM Methodology Panel, 2008) and in the recently adopted 'Guidelines for objective demonstration and assessment of barriers' (CDM Executive Board, 2009).

A quick exploration of the data provided by the IGES CDM Project Database (IGES, 2010), which includes information on what type of financial analysis is used in each CDM project, shows that of all the CDM projects already registered, or seeking registration, by the end of 2009, around 35% do not provide any financial data in their public documentation. The factors affecting the decision to include a financial analysis in the CDM project documentation are, as will be discussed in detail below, not only the technology involved in the project, but also the size of the project, the host country and notably the time passed since the CDM was initiated. This leads us to believe that the data do not suffer from selection bias.

It can be assumed that the technology involved in the project is the main determinant of the project's cost such that, if the cheap technologies never provide financial information, there will be selection bias. In CDM projects, the technology used is roughly determined by the 'project type', which is a classification that includes both the economic sector involved (e.g. energy, agriculture, forestry, cement industry) and the generic technology used to reduce emissions (wind energy, hydro power, reforestation, energy efficiency improvements). In the IGES data, it can be seen that in terms of project types, only the projects reducing the industrial gas HFC-23 (a very potent GHG) never perform the financial analysis, which is because they are almost automatically considered additional, as they do not have any revenues other than the CERs. In all other project types (except in those that have only one or two projects registered), at least 30% of the projects provide some kind of financial data. Thus, for almost all project types there is some cost data available. This minimizes the risk of selection bias.

The size[6] of the project is also an important variable affecting the decision to include a financial analysis in the documentation. Almost 80% of the large CDM projects include a financial analysis, while only 45% of the small ones do. This is related both to the simplified modalities for additionality determination that exist for small projects, and to the above-mentioned regulatory mistrust against the barrier test. With respect to countries, in all main CDM hosts both projects with and without a financial analysis are found but there are considerable differences: in China, for example, over 90% of projects include some kind of financial data, while in Mexico and India only 71% and 45%, respectively, do so. Finally, the time elapsed since the first CDM project was submitted for validation (December 2003) increases the likelihood that a new project includes a financial analysis in its documentation, and this is applicable to most project types. Indeed, as the CDM rules have become clearer and stricter over time, more projects have chosen to perform an investment analysis to demonstrate additionality.

5.2 CDM-specific abatement cost calculation

As shown in Equation 1, a project's abatement costs is defined as the net present value of the project costs (investment and operation) minus its revenues (e.g. income from electricity sales), all divided by the amount of GHG emission reductions it expects to achieve (indicated by the amount of emission reduction credits the project expects to generate over its crediting lifetime, also time-discounted)[7]:

$$C(CDM)_i = \frac{\sum_{t=1}^{n} \frac{(C_t - R_t)}{(1+r)^t} + I_0}{\sum_{t=1}^{m} \frac{A_t}{(1+r)^t}} \qquad (1)$$

Where $C(CDM)_i$ is the abatement cost of project i in USD/tCO_2e, t the time period, n the operative lifetime of the project and m its crediting period (all in years); C_t and R_t the operation costs and the non-carbon revenues in year t, and I_0 the initial investment; A_t is the abatement achieved by the project in year t (in tCO_2e); and r is the discount rate. All costs are expressed in US dollars, calculated either using the current interbank exchange rate at the time the project was proposed, or using the exchange rate provided by the project developer in the documentation. This cost calculation approach is similar to the one used by Rahman et al. (2009) in a recent empirical study on the cost structure of CDM emissions abatement, but our calculations differ on the treatment of the annual abatement, which are discounted in order to be able to interpret abatement costs in constant terms (however, our main results are not affected if undiscounted emission reductions are used in the denominator).

Time discounting is critical in cost calculations. In capital budgeting, time discounting is used to reflect the interest rates the project is subject to, plus any financial risks applicable to either the country where the investment is taking place or the type of investment being made (Brealey and Myers, 2000). In the CDM, discount rates are chosen by the project participant, but need to be justified. Still, there is a significant variation in the financial discount rates of projects in different technological categories and in different countries. The discount rates have been standardized for each country in order to have comparable information and to avoid the possible effect of discount rates being manipulated to obtain less attractive financial figures.[8] The discount rate chosen for each country is the median of the discount rates utilized in the CDM projects within the sample taking place in the respective country, which was then rounded to the closest integer. As project developers have to substantiate the parameters they choose for the financial analysis, we consider the median to be a good indicator of the real discount rate applicable in the country. This is preferable to the mean, because it avoids the influence of outliers, and to the mode because in several countries no mode was found, and in most cases the median and the mode were identical.

See Appendix 1 for an overview of the standardized discount rates applied. See also Castro and Michaelowa (2010) for further details on the methodology used for the cost calculations.

Abatement cost information was extracted from 304 CDM projects, covering 36 emission reduction technologies.[9] These projects are mainly located in the eight host countries included in the sample (see below). For technologies where no sufficient financial information was found in these countries, the sample was extended to other countries. For the reason described above, HFC-23 reduction projects, which contribute a large percentage of the CERs generated in advanced developing countries, typically lack financial data in the project documentation; thus, abatement cost estimations from secondary sources (Harnisch and Hendricks, 2000; Jimenez, 2005; UNEP TEAP, 2002) were used.

The resulting abatement cost data were summarized in terms of the median abatement cost estimated for each technology (or CDM project type) included in the sample.

5.3 Expected size of CDM emission abatement

As an estimation of the amount of mitigation opportunities the CDM is expected to capture in a country, the annual amount of carbon credits that all the CDM projects currently proposed in the country estimate was aggregated. This information was taken from the CDM pipeline as of the end of December 2009 (URC, 2010). This is a rough estimation, as it does not include new projects that could be proposed in the future, but does include projects that have been proposed but not yet registered so far. Following current project proposal rates (91 projects/month[10]), about 1092 new projects will enter the CDM pipeline by the end of 2010. Following current project registration rates (47 projects/month[10]), only about 564 existing projects will be registered. As the CDM pipeline includes 2838 not-yet-registered projects as of the end of December 2009, our estimation is likely to be larger than the real size of the CDM by the end of 2010, because many projects in the pipeline will not yet start generating emission reduction credits (unless the registration process accelerates significantly in the following months, which is unlikely). Finally, this estimation does not take into account the fact that the emission reductions actually achieved are – for most project types – less than the estimations provided in the project documentation (Castro and Michaelowa, 2008; URC, 2010). This all implies that, for our discussion of the low-hanging fruit argument, we are again on the safe side: if an overestimated CDM does not capture a large proportion of the theoretical abatement potential, then the low-hanging fruit issue is not likely to be a real problem.[11]

5.4 Comparison with theoretical abatement cost studies

From the cost and the size information, marginal abatement cost (MAC) curves for the CDM were built. In order to test the size hypothesis, these curves were compared with MAC curves showing the technical emissions abatement potential in the respective country. These theoretical MAC curves were built by merging the information from several studies that have performed bottom-up assessments of the technologies available for reducing GHG emissions in individual countries, their costs, and the amount of emission reductions that could potentially be achieved (the details of the studies used appear in Appendix 2). Care was taken to avoid overlaps between the different studies. In order to test the cost hypothesis, a more detailed analysis of the portion of the abatement potential captured by the CDM for different cost categories was performed.

5.5 Case selection

The low-hanging fruit argument is of interest to those developing countries under pressure to take more action to mitigate climate change. Action towards climate change mitigation is subject to the principle of 'common but differentiated responsibilities and respective capabilities' of countries (UNFCCC, 2008, p.3), which means that countries with more responsibility for causing climate change and with better capabilities to take action should do more. Responsibility can be measured in terms of GHG emissions levels, in absolute terms or per capita. Capability can be measured in terms of GDP per capita, which is an indication of the economic wealth of the country. Further, the low-hanging fruit problem is potentially relevant only to those countries in which the CDM has become significant.

Thus, from the countries that are hosting at least 10 registered CDM projects, those that ranked highest, in terms of absolute CO_2 emissions, CO_2 emissions per capita and GDP per capita, were taken by building an index that incorporates these three indicators with equal weights. Data was obtained from IEA (2007) and IMF (2008). The resulting sample includes China, South Korea, Mexico, South Africa, Thailand, Argentina, Malaysia and Israel. For Malaysia and Israel it was not possible to collect sufficient information for building theoretical abatement cost curves, hence they are discarded from the analysis.[12] However, they have been used for extracting CDM project cost information. India and Brazil, two important CDM host countries, are not covered in the sample: India has very low levels of emissions per capita and GDP per capita; Brazil has very low levels of emissions per capita and its emissions come mainly from the land use sector, which is currently not covered under the CDM. Chile had an index value very similar to the one of Argentina. As Argentina has higher absolute emissions, this country was preferred for the analysis.

6. Results

6.1 CDM abatement costs

Figure 1 shows box plots of the estimated emissions abatement costs of the projects in the sample, after standardizing their financial discount rates.

Figure 1 about here

The graph shows that, even after standardizing discount rates, there is a high variability in cost estimations for some technologies, and thus these estimations need to be taken with care. However, our results reproduce very closely the range and ranking of costs reported in abatement cost studies (see e.g. US EPA, 2006; Vattenfall, 2007; Wetzelaer et al., 2007): Methane and industrial gas reduction projects are generally cheaper than CO_2 reduction projects, basically due to the higher global warming potential of these other gases; renewable energy projects, specifically wind, hydro and solar energy projects are among the costlier ones. All this is consistent with other marginal abatement cost curves and supports our results. The abatement costs of most of these CDM projects are significantly below US$ 13, which is an indication that the emission credit income at current primary prices will make them attractive.[13]

The variability of costs within project subtypes stems from various factors. The impact of financial discount rates has already been discussed. These and other parameters (project lifetimes, inclusion of taxes and financing costs) can be easily manipulated to make projects appear non-attractive. However, there are also large differences in the technologies used within project subtypes. For example, methane recovery projects from wastewater can consist of a sophisticated bioreactor, or of a plastic membrane covering an already existing anaerobic lagoon. Biodigesters can be imported or can be manufactured domestically, which also has an impact on costs. Biomass projects include energy generation from a variety of agricultural or industrial by-products, involving different technologies. Energy efficiency projects take place in cement, steel, chemical, petrochemical and other industries and can encompass different efficiency measures. Hydroelectric projects have very different sizes, and smaller ones (involving the construction of a dam) typically imply higher abatement costs. Finally, different countries can have different cost structures, energy prices, taxes or financial incentives for specific technologies, which may have an impact on overall abatement costs.

6.2 CDM abatement cost curves

Figures 2(a) and 2(b) show the estimated GHG abatement cost curves for the CDM of China and the other countries. As explained, these curves were built by taking the median abatement cost of each technology (shown in Figure 1) and the amount of emission reductions expected to be achieved annually by all CDM projects in the pipeline as of December 2009 in the respective countries, also classified by technologies.

Figure 2 about here

It should be noted that these curves include project types without cost information. These appear at the left end of the curves, as having zero abatement costs. The projects without cost information represent 5.2% of the CDM abatement potential in South Korea, 2.2% in Thailand, 0.7% in Israel, 0.1% in China and 0% in Argentina, Malaysia, Mexico and South Africa. While this inclusion enlarges the quantity of low-cost (or zero-cost) project options, these data were not omitted from the curves as they allowed for a more realistic picture of the overall abatement potential. This enables us again to be on the cautious side of the estimations.

6.3 Comparison with theoretical abatement curves: size

Based on data reported in 18 climate mitigation studies in the countries included in the sample (see Appendix 2), theoretical GHG abatement cost curves were built, trying to cover as many emission reduction options from as many economic sectors as possible, and including CO_2, methane and, when information was available, industrial gas emissions. In all countries, the curves were built to reflect the emissions reduction potential in the year 2010, which should be comparable to the current CDM in which a static stock of mitigation options is assumed. In the Chinese case, an abatement curve for the year 2020 has also been included, to provide an idea of how the emissions reduction potential is expected to grow in the future.

The indicator of the size component of the low-hanging fruit argument is provided by the horizontal difference between the CDM-specific and the theoretical abatement cost curves in each country. This is shown in Figures 3 (a)-(f). Table 1 presents a summary of calculations regarding how much of the theoretical abatement potential in each country is being captured by the CDM, by dividing in each case the total abatement expected from the CDM by the total theoretical abatement potential.

Figure 3 about here

Table 1 about here

Figure 3 and Table 1 show that, in all cases, the CDM is capturing only a portion of the estimated emissions reduction potential in the respective countries. In China this portion is around 32%, thus it could be said that there is a risk that the CDM is exhausting the stock of emission reduction possibilities in the country. However, as time passes, new mitigation opportunities arise, so that the current CDM represents only about 22% of the Chinese emission reduction potential in 2020. In South Korea and Argentina, the CDM has captured less than 20% of the potential identified up to 2010, and in Mexico, South Africa and Thailand this portion is below 10%. Thus, we see that in most countries, the risk of a 'low-hanging fruit issue' is, at least in terms of the current size of the CDM, weak.

Looking in more detail at which technologies have been taken up by the CDM, Table 2 shows the portion of the theoretical potential that is being captured by each technological category. The table shows that, in some sectors, such as agriculture and energy efficiency, very little of the identified potential has accessed the CDM. In other sectors, on the contrary, much larger emission reductions are being realized through the CDM than those identified in the theoretical studies, mainly in energy generation from renewable or other sources, or in reduction of industrial gases.

While it appears that the CDM concentrates in specific technological niches, it is clear that the theoretical abatement studies did not uncover all the existing potential. The projections have been too conservative, especially in energy generation, where many countries have experienced an unprecedented growth (for example the explosion of wind power capacity in China since 2006, which was not foreseen by the analysts) and where the potential for renewables is difficult to estimate. Again, because of this, the conclusions that are drawn remain on the cautious side of whether the CDM is exhausting the mitigation potential.

Table 2 about here

Figure 3 and Tables 1 and 2 compare the CDM to theoretical abatement curves that were built on the basis of literature research, but resulted in some mismatch because the CDM uncovered significant emission reduction possibilities that had not been identified by the previous theoretical abatement potential studies. A more correct comparison would thus be between the CDM and a completed theoretical abatement that includes both the forecasts from the literature and the extra abatement (beyond the forecasts) achieved by the CDM. Such a comparison would imply that the CDM has captured even a smaller portion of the abatement potential than estimated in Tables 1 and 2, strengthening our conclusions.

An attempt to depict this situation appears as Figure 4, where, for the case of China, four abatement cost curves were compared: that of the CDM projects registered up to December 2009, which represents the lower range of annual abatement that will be achieved by the CDM; that of all CDM projects in the pipeline by December 2009, representing the higher range of abatement that will be achieved by the CDM under current rules up to 2012 (this is the same curve as in Figure 3); that of the incomplete theoretical abatement potential by the year 2010, gathered from the literature (same curve as in Figure 3); and that of a completed theoretical abatement potential that results from adding the extra abatement opportunities uncovered by the CDM to the previous curve. If this last curve is taken as being the real theoretical abatement potential in China, the CDM would capture 28% of the theoretical potential under the high-range CDM abatement scenario, which shows again that the results presented above are conservative in terms of the relevance of the low-hanging fruit problem.

Figure 4 about here

6.4 Comparison with theoretical abatement curves: costs

In all countries analysed, the cost range of the CDM projects (vertical axis in the abatement cost curves) covered only a fraction of the theoretical abatement cost range. This is analyzed in more detail in Table 3. In China, South Korea and Thailand, it is observed that the CDM captures some very costly emission reduction options. These are solar energy projects, subsidized in the latter two countries through feed-in tariffs. In China and South Africa some CDM projects reach abatement costs of nearly $50-70, which is also above the market price for emission reductions. In Mexico and Argentina, finally, the CDM mainly stays below the $13 threshold, so that the CER primary price makes most projects attractive. From this analysis, it can be concluded that in Mexico and Argentina the CDM seems to be focusing almost exclusively on the cheaper projects, while in the other countries there is also some (albeit marginal) exploration of higher cost emission reduction opportunities.

Table 3 about here

In several theoretical GHG abatement cost studies consulted (Johnson et al., 2009; Wetzelaer et al., 2007; Enkvist et al., 2007; Bakker et al., 2007; US EPA, 2006; World Bank, 2002; UNDP/GEF, 1999; ADB, 1998a, 1998b), the estimated potential of GHG reduction options with net negative costs is significant. Such 'no-regret' reduction options seem to conflict with rational behaviour: if an investment entails negative costs, it is financially profitable, and this business opportunity should have been captured. The reasons for the existence of this negative-cost potential are market imperfections leading to lack of knowledge about the reduction options, misaligned incentives, social preferences, a lack of priority, insufficient capital availability and differing definitions of cost (e.g. social versus financial cost). It is often suggested that in order to remove these market barriers, high transaction costs are incurred, which are normally not included in abatement cost studies.

The CDM imposes further costs to these abatement options, especially to small-scale ones: monitoring methodologies need to be designed and approved; project design, validation, registration and verification of emission reductions need to be paid for; monitoring plans and equipment need to be put in place. It is thus not too surprising that the large reduction potential from energy efficiency and transport, typically with abatement costs below zero, is not being taken up by the CDM.

The observation that many theoretically cheap abatement options remain on the table in developing countries reflects the limitations of the CDM for overcoming non-market barriers to these abatement options. From this point of view, it is argued that the CDM has grasped the cheap abatement options that have been easy to obtain, while mostly leaving alone the abatement options that are more difficult to implement in practice.

7. Conclusions and limitations of the study

An attempt to use empirical data to test the low-hanging fruit hypothesis regarding the CDM – the claim that it is using up the cheaper emission reduction options in its host countries, thereby leaving them without future opportunities for cost-effective emission reductions when they adopt climate change mitigation commitments - was presented. By comparing the portion of the emissions reduction potential in six countries captured so far by the CDM with the potential available according to several studies, it is concluded that the low-hanging fruit argument is weak.

It was found that the CDM is not yet taking up a large portion of the identified theoretical abatement potential in most of the countries assessed, with the exception of China where it reaches about 32%. In terms of costs, while most of the emissions reduction opportunities grasped by the CDM are below the average market price, there is still plenty of low-cost opportunities to be harvested. Finally, while Mexico and Argentina appear to use the CDM almost exclusively for harvesting the low-hanging fruit, more expensive projects are accessing it in the other countries analyzed (China, South Korea, Thailand and South Africa) . A more detailed study of why these more expensive projects are being captured could shed further light on how to direct the CDM for both promoting technologies that are usually difficult to access and encouraging learning effects, thereby creating new 'low-hanging fruits'. Further, recognition of the transaction costs and non-market barriers involved in the implementation of many theoretically cheap abatement options may explain why many of these options are still left untouched.

Even with these results, if the CDM (or a similar offsetting mechanism) is expanded significantly, there is a risk that cheap abatement options may become scarce in the countries involved. Programmatic CDM, which is only just taking off, can open the door for projects in rarely covered sectors (e.g. households and small-scale renewables). Potential changes in the rules of the CDM, allowing for the inclusion of carbon capture and storage (CCS); nuclear energy; avoided deforestation; other land use, land use change and forestry (LULUCF) projects; and the abatement of GHGs currently not covered by the Kyoto Protocol, could also lead in this direction. The market mechanisms currently under discussion in the negotiations– sectoral crediting, or credited NAMAs (Nationally Appropriate Mitigation Actions) – could also expand offsetting significantly. While these new approaches will only materialize if there is sufficient demand for emission reduction credits from countries with emission reduction targets, careful design is needed to keep positive incentives for mitigation in developing countries.

Finally, a note on the limitations of this study. While data on emission reduction costs and potentials was collected from as many sources as possible, the theoretical potential identified is quite conservative, as illustrated by the many emission reduction options that the CDM has captured without first being identified in the theoretical studies. This implies both that the MAC curves presented here are to be used with care, and that our result – that the CDM is not yet capturing a large portion of this potential – is robust. Further, cost data from CDM projects is likely to be biased downwards for costly technologies and upwards for cheap technologies. The reason for this bias is that CDM projects need to demonstrate that they are financially unattractive without the CDM revenues, but the input of CDM revenues make them attractive. The few, very expensive, projects found in the CDM acknowledged that they were not financially feasible, but were intended for demonstration purposes. Finally, even if this possible bias is disregarded, CDM cost information was mainly gathered from the six countries the study focuses on. This renders the project sample by technologies or project types quite small in some cases. Thus, it is likely that geographical and technological differences lead to more variability in terms of abatement costs within project types than is reflected here. Further effort in collecting data from more countries could lead to more detailed technological categories with more accurate cost data.

Endnotes

1. In the Kyoto Protocol, industrialized countries with mandatory emission reduction targets for the period 2008-2012 are listed in Annex B, thus being known as 'Annex B countries'. Annex B is an update of the UNFCCC's Annex I, which lists the countries that were members of the OECD (Organization for Economic Co-operation and Development) in 1992, plus countries with economies in transition. Under the UNFCCC, these countries agreed to reduce GHG emissions to 1990 levels by the year 2000. Countries in both lists are the same, except for Belarus and Turkey which do not appear in Annex B. In this article, countries with emission reduction targets will frequently be referred to as 'industrialized countries', and countries without targets ('non-Annex B countries') as 'developing countries'. As such, some rapidly

industrializing countries such as China, and some South-East Asian and oil exporting countries of the Gulf region, qualify as 'developing countries'.

2. See Narain and van't Veld (2008) for a review of occasions when the low-hanging fruit issue was discussed in the Kyoto negotiations.
3. Recent calculations suggest that China is now the largest CO_2 emitter in the world, surpassing even the USA (MNP, 2008; IEA, 2010). However, per-capita emissions in this and other large developing countries are still very low in the global ranking.
4. In order to be registered, CDM projects need to demonstrate that they would not have happened without support from the CDM (the additionality rule). Thus, if in country X there is a piece of legislation that mandates, for example, the use of energy saving lamps, then country X cannot propose a CDM project to replace incandescent bulbs with energy saving ones. The additionality rule discourages countries from passing climate-friendly legislation, because they do not want to lose the potential revenues from possible CDM projects. To avoid this perverse incentive, the CDM authorities created a new rule in November 2005, which states that climate-friendly policies passed after the year 2001 are not to be counted towards the additionality constraint of CDM projects.
5. Each project has a standardized 'Project Design Document' (PDD), which is used throughout the registration process and is publicly available for analysis.
6. In the CDM, the size of the project is determined either in terms of its output capacity (for renewable energy projects), the amount of energy consumption reduced (for energy efficiency projects), or the amount of emission reductions achieved (for all other projects) (CDM Rulebook, 2010). Projects considered to be small according to these criteria can use simplified baseline and monitoring methodologies, which include, among others, a simplified demonstration of additionality.
7. In this definition, the savings in energy consumption or the cost of alternative investments are also considered as revenues, so that the incremental costs of emission reductions constitute our abatement costs.

8. Project developers have an incentive to manipulate their figures and try to show low revenues, so that the project appears financially unattractive, which is a prerequisite for being considered additional.
9. 94% of the analysed projects are already registered under the CDM Executive Board of the UNFCCC. Projects at an earlier stage of the registration process were analysed only if no sufficient information was available from registered projects for a certain technology. In this case, care was taken that any requests for review were not related to the financial analysis of the project.
10. Average over the last 3 months of 2009.
11. It should be noted that performance in terms of actual generation of emission reductions differs between CDM project-types, with industrial gas projects clearly generating more reductions than initially projected, and methane reduction projects generating less. While taking this into account affects our estimation of CDM size for specific technological and cost categories (shown in Tables 2 and 3), it does not affect the main conclusion that the low-hanging fruit argument is weak. Calculations using issuance-corrected CER volumes are available on request.
12. The consultancy McKinsey has prepared a MAC curve for Israel, but the full report is only available in Hebrew, and the executive summary in English does not provide sufficient information for our purposes. Further, it focuses on the year 2030, which is too far away in the future to compare with the CDM now.
13. According to the monthly newsletter 'CDM Highlights' issued by GTZ, CDM credit prices fluctuated between USD 12 and USD 33 in the spot market during 2008 and 2009, with an average of USD 20.7. The World Bank's *State and Trends of the Carbon Market* (Kossoy and Ambrosi, 2010) cites an average price of $12.7 per CER in the primary market during 2009. While it is difficult to choose between primary and secondary prices as the correct threshold for defining a cheap abatement option (as project developers in different countries have different CER selling strategies), the conclusion remains unchanged if the $12.7 or the $20.7 average price is used. The conclusion also remains unchanged if it is considered that CDM transaction

costs should be added to the pure abatement costs before assessing the financial attractiveness of the project.

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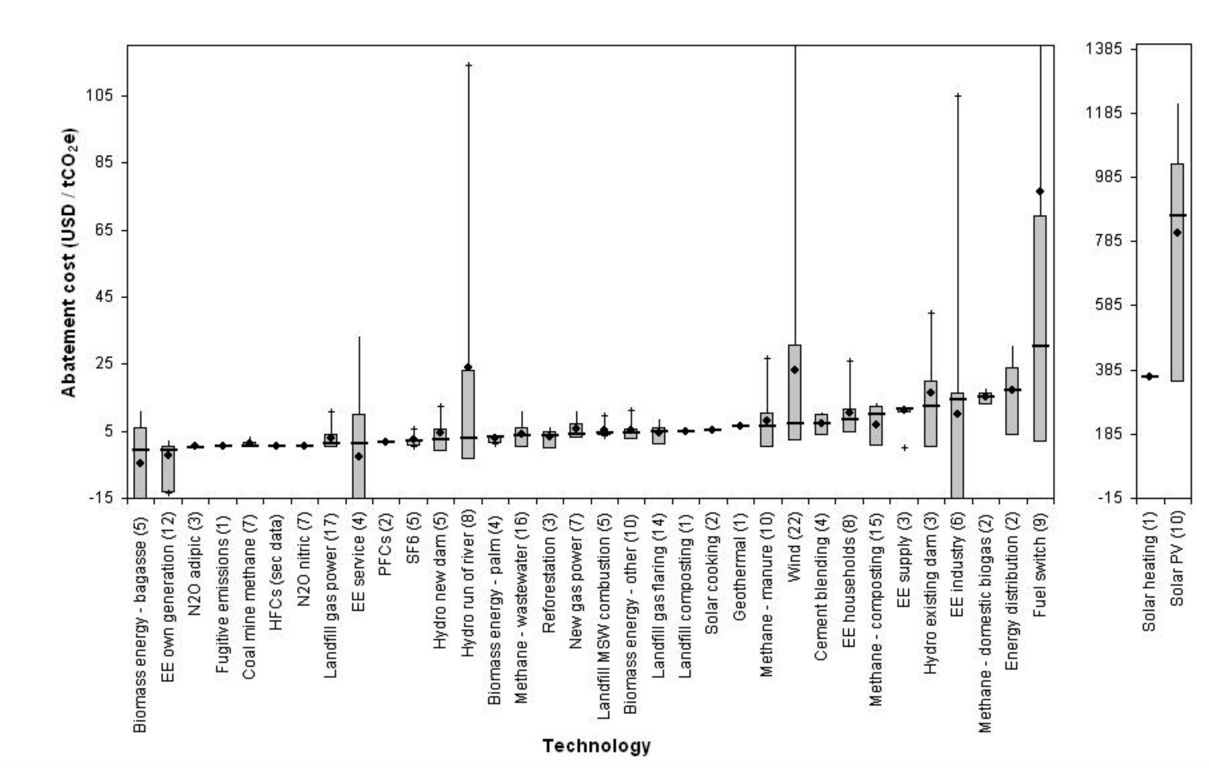
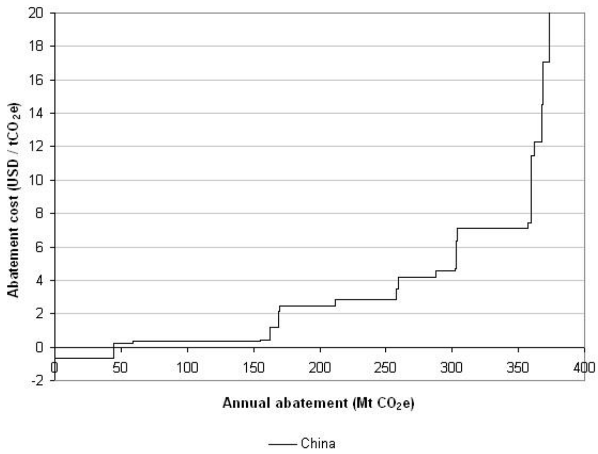
Figure 1: Estimated abatement costs of CDM projects (USD/tCO2e), by technology



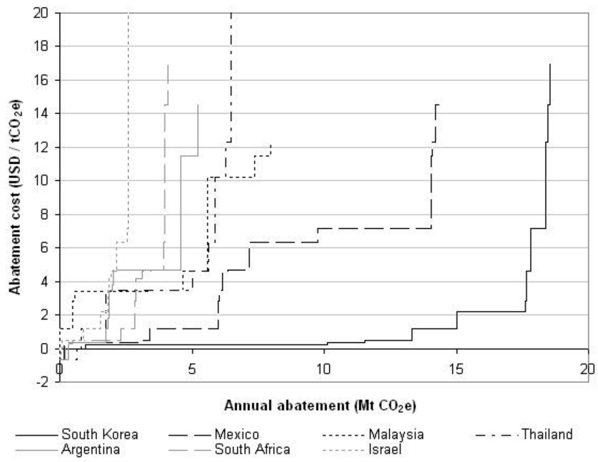
Sources: CDM projects' Project Design Documents, own calculations. For HFC projects: Harnisch and Hendricks, 2000; UNEP TEAP, 2002; Jimenez, 2005. The figures in parentheses show the sample size for each technology.

Figure 2: GHG abatement cost curve for the CDM pipeline

(a): China

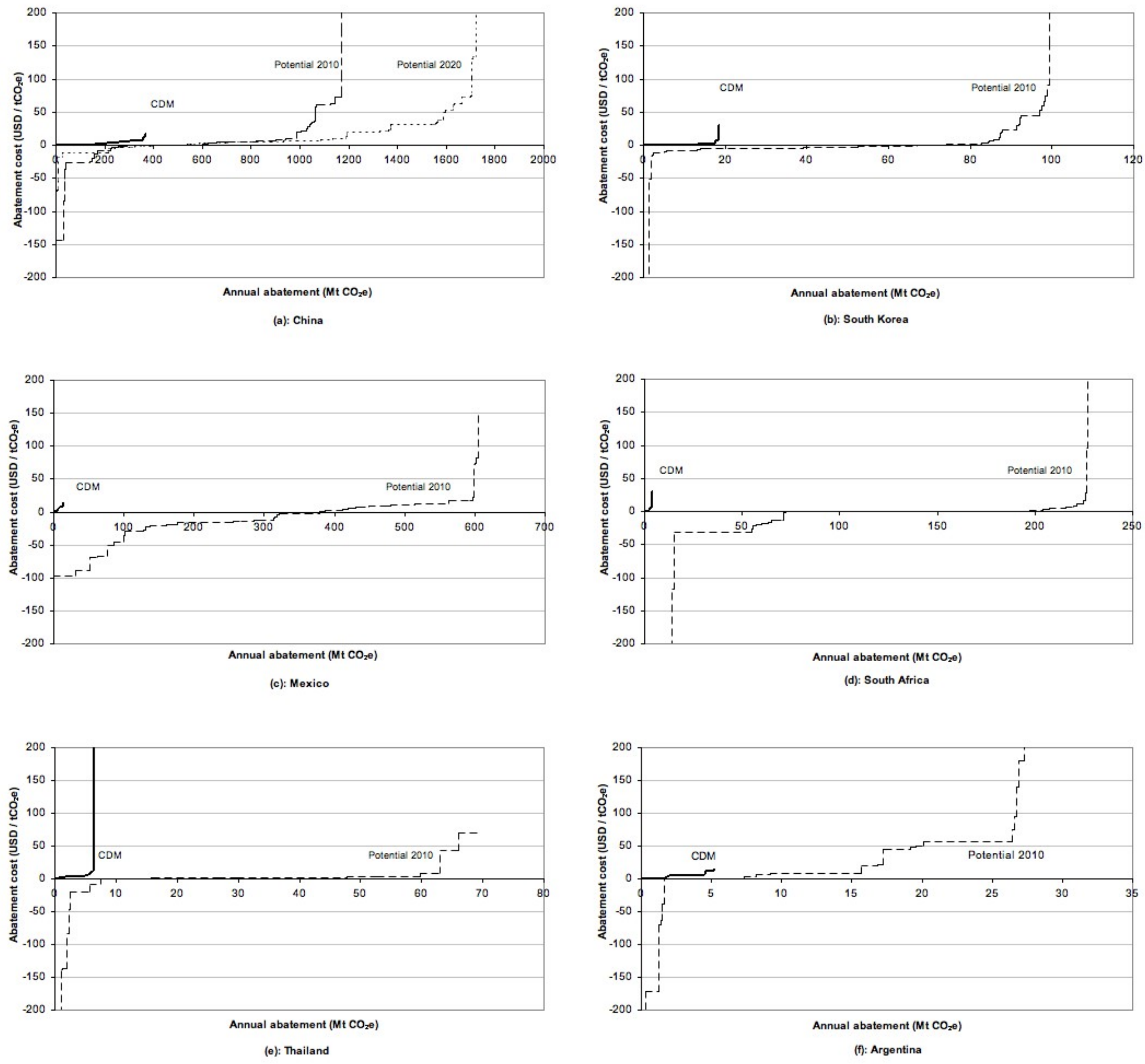


(b): South Korea, Mexico, Malaysia, Thailand, Argentina, South Africa, Israel



Sources: Cost data from PDDs, potentials from URC (2010), own calculations.

Figure 3: Comparison between expected CDM abatement and potential abatement



Note: The potential abatement curves are built on the basis of data from the studies listed in Appendix 2. They do not include emission reduction opportunities that were uncovered by the CDM and had not been previously forecast in the mentioned studies.

Figure 4: China: Comparing actual CDM, potential CDM, theoretical potential and completed theoretical potential

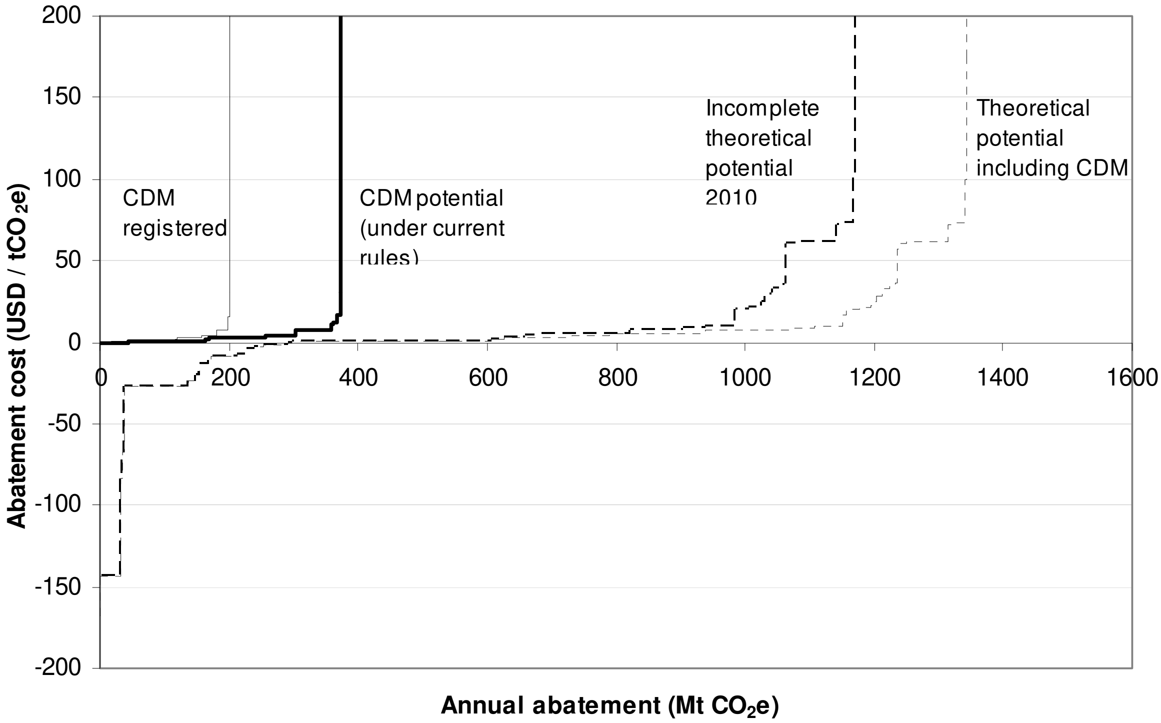


Table 1: Emissions abatement potential captured by the CDM

Country	Percentage of abatement potential captured by CDM
China	31.9% of 2010 potential
	21.7% of 2020 potential
South Korea	18.4% of 2010 potential
Mexico	2.4% of 2010 potential
South Africa	1.9% of 2010 potential
Thailand	9.4% of 2010 potential
Argentina	17.7% of 2010 potential

Note: Percentages based on the incomplete theoretical abatement potential (without including emission reduction opportunities that were uncovered by the CDM and had not been previously forecast).

Table 2: Emissions abatement potential captured by the CDM, by technologies

Technological category	Percentage of abatement potential captured by CDM					
	China	South Korea	Mexico	South Africa	Thailand	Argentina
Agriculture	0.0%	0.0%	0.0%	-	-	-
Coal mine methane	15.9%	-	25.7%	0.0%	-	-
Energy efficiency in households / commercial buildings	0.1%	0.0%	0.0%	0.0%	0.0%	-
Energy efficiency in industry	0.3%	0.2%	3.4%	0.3%	0.0%	2.2%
Energy efficiency in own generation	19.0%	0.0%	0.4%	infinite	20.2%	75.4%
Thermal power	27.7%	0.0%	0.1%	2.9%	0.0%	-
Forestry	0.4%	0.0%	0.0%	0.0%	0.0%	2.2%
Fugitive emissions	3.2%	0.0%	2.2%	infinite	-	-
Industrial gases	73.5%	218.6%	171.9%	infinite	infinite	infinite
Renewable energy	678.2%	infinite	4.4%	4.5%	infinite	0.9%
Other energy	880.7%	6.6%	0.0%	0.1%	0.0%	35.0%
Waste	7.6%	9.4%	38.1%	64.4%	infinite	48.5%
Transport	Infinite	0.0%	0.0%	0.0%	0.0%	0.0%

Note: Percentages based on the incomplete theoretical abatement potential (without including emission reduction opportunities that were uncovered by the CDM and had not been previously forecast). “Infinite” denotes a category, for which the theoretical abatement studies did not identify any emission reduction potential, but the CDM did nonetheless. “-“ denotes a category where no emission reduction opportunities were identified, neither in the CDM, nor in the theoretical studies.

Table 3: Emissions abatement potential captured by the CDM, by cost categories

Cost category	Percentage of abatement potential captured by CDM					
	China	South Korea	Mexico	South Africa	Thailand	Argentina
< 0 USD/tCO_2e	3.0%	0.1%	0.1%	0.4%	8.6%	18.9%
0 - 10 USD/tCO_2e	27.9%	82.6%	11.0%	2.5%	10.2%	30.2%
10 - 20 USD/tCO_2e	148.5%	288.7%	0.2%	0.3%	infinite	55.8%
20 - 30 USD/tCO_2e	89.4%	0.0%	137.8%	0.0%	-	3.7%
30 - 40 USD/tCO_2e	126.9%	2.6%	-	-	-	-
40 - 50 USD/tCO_2e	0.0%	0.0%	-	0.0%	0.0%	0.7%
50 - 60 USD/tCO_2e	2392.1%	0.0%	0.0%	-	-	0.2%
60 - 70 USD/tCO_2e	0.2%	65.8%	-	infinite	0.0%	-
70 - 80 USD/tCO_2e	0.2%	0.0%	0.0%	-	-	0.0%
> 80 USD/tCO_2e	2.7%	13.8%	0.0%	0.0%	infinite	0.9%

Note: Percentages based on the incomplete theoretical abatement potential (without including emission reduction opportunities that were uncovered by the CDM and had not been previously forecast). "Infinite" denotes a category, for which the theoretical abatement studies did not identify any emission reduction potential, but the CDM did nonetheless. "-" denotes a category where no emission reduction opportunities were identified, neither in the CDM, nor in the theoretical studies.

Cost categories were defined by matching technologies used in the CDM with technologies included in the theoretical studies, and taking the abatement costs estimated in the theoretical studies. For technologies appearing in the CDM and not in the theoretical studies, our estimation of abatement costs was taken.

Appendix 1: Standardization of discount rates

Country	Standardized discount rate
Argentina	11%
Brazil	15%
China	8%
Ecuador	12%
India	11%
Indonesia	17%
Israel	10%
Jordan	8%
Kenya	15%
Malaysia	10%
Mexico	12%
Moldova	10%
Morocco	10%
Mozambique	13%
Peru	12%
Philippines	12%
Qatar	10%
Rwanda	12%
South Africa	12%
South Korea	7%
Thailand	10%
United Arab Emirates	8%

Appendix 2: Sources of data for theoretical MAC curves

Country	Data sources
Argentina	National CDM/JI Strategy Studies (NSS) Program, 1999; UNDP/GEF, 1999
China	Yamaguchi, 2003; Yamaguchi, 2005; US EPA, 2006; Wetzelaer et al., 2007; Cai et al., 2008
Mexico	Sheinbaum and Masera, 2000; US EPA, 2006; Bocanegra, 2009; Johnson et al., 2009
South Africa	World Bank, 2002; Winkler et al., 2008
South Korea	Asian Development Bank, 1998a; Roh, 2006a; Roh, 2006b; Roh and Kang, 2006; US EPA, 2006
Thailand	Asian Development Bank, 1998b; Shrestha and Bhattacharya, 2002